MOVEMENTS AND SURVIVAL OF FLEDGLING COOPER'S HAWKS IN AN URBAN ENVIRONMENT

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ABSTRACT.—Cooper's Hawks (*Accipiter cooperii*) nest in urban and suburban areas across North America, but little is known about movements, habitat use, or survival of fledglings in these settings. We followed 40 radio-tagged, fledgling Cooper's Hawks hatched in Tucson, Arizona in 1999 or 2000, for up to 6 mo to estimate survival, and describe patterns of movement and the environments they use while dispersing. The typical pattern of movement for hawks we tracked through early winter consisted of sedentary behavior in the natal area, followed by relatively long movements beginning 11–13 wk after hatching, and finally sedentary behavior again when they settled into a fall/winter home range. Distances between relocations of individual hawks were, on average, greater for females ($\bar{x}$ = 6.8 km, range = 0.02–51.7 km, SD = 9.8) than males ($\bar{x}$ = 3.8 km, range = 0.05–20.8 km, SD = 5.4; *t*-test, P = 0.02). Home range size for nine hawks during their first fall/winter averaged 771 ha (SD = 403). Distance from center of home range to natal site averaged nearly twice as far for females ($\bar{x}$ = 10.9 km, range = 4.2–19.5 km, SD = 6.4) as males ($\bar{x}$ = 6.0 km, range = 2.2–13.3, SD = 5.0), but the difference was not significant (*t*-test, P = 0.23). Survival of radio-tagged hawks was 67% through 180 d. Hawks used a variety of environments prior to settling for the winter, but were found most frequently (35% of locations) in riparian areas. We found no discernable pattern of habitat selection for land use categories inside winter home ranges. We speculate that the abundance of food may facilitate survival of post-fledging, dispersing hawks in Tucson.

KEY WORDS: *Cooper's Hawks*; Accipter cooperii; *dispersal*; *habitat selection*; *home range size*; *urban environments*; *Tucson, Arizona.*

MOVIMIENTOS Y SUPERVIVENCIA DE POLLUELOS DEL GAVILAN DE COOPER EN UN AMBIENTE URBANO

RESUMEN.—El gavilán de Cooper (*Accipiter cooperii*) anida en áreas urbanas y suburbanas a lo largo de Norteamérica, y se conoce poco acerca de sus movimientos, uso de hábitat, o sobre la supervivencia de los juveniles en estas localidades. Seguimos 40 gavilanes de Cooper juveniles equipados con radios de telemetría empollados en Tucson, Arizona en 1999 o 2000, por cerca de 6 meses para estimar su supervivencia, y describir los patrones de movimiento y los ambientes que ellos usan durante su dispersión. El patrón típico de movimiento para los gavilanes que seguimos a principios del invierno consistió de un comportamiento sedentario en el área natal, seguido por movimientos relativamente largos que comienzan en la semana 11–13 luego de romper el cascaron, y finalmente un comportamiento sedentario de nuevo cuando se establecen dentro de su rango de acción de la temporada otoño/invierno. Las distancias entre las reubicaciones individuales de los gavilanes fueron, en promedio, más grandes para las hembras ($\bar{x}$ = 6814 m, rango = 16–51 673 m, SD = 9752) que para los machos ($\bar{x}$ = 3776 m, rango = 46–20 759 m, SD = 5356) (test de T, P = 0.02.) El tamaño del rango de acción para nueve gavilanes durante su primer otoño/invierno promedió 771 ha (SD = 403.) La distancia del centro del rango de acción al sitio natal fue en promedio cerca de dos veces más lejana para las hembras ($\bar{x}$ = 10.9 km, rango = 4.2–19.5 km, SD = 0.387) que para los machos ($\bar{x}$ = 6.0 km, rango = 2.2–13.3, SD = 5.0), pero la diferencia no fue significativa (test de T, P = 0.23). La supervivencia de los gavilanes monitoreados fue del 67% para 180 días. Los gavilanes usaron una variedad de ambientes antes de establecerse para el invierno, sin embargo se encontraron mas frecuentemente (35% de las ubicaciones) en zonas riparias. No encontramos ningún patrón discernible en la selección del hábitat para las categorías del uso del suelo dentro de los rangos de acción invernales. Especulamos que la abundancia de alimento puede facilitar la supervivencia de los gavilanes juveniles que se dispersan en Tucson.

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Natal dispersal in birds is the movement of fledglings away from their nests and often involves a search by dispersing individuals for a place to reside and potentially breed. Distances traveled by dispersing birds and their survival can significantly affect the genetic structure, demography, and viability of bird populations (e.g., Pulliam and Danielson 1991, Payne and Payne 1993, Clobert et al. 2001). Natal dispersal usually is measured as the straight-line distance between natal nests and sites where birds first breed, if they survive (Howard 1960, Greenwood and Harvey 1982). But dispersal generally takes place in landscapes composed of patches that vary in size and quality relative to the needs of dispersing individuals; thus, movements between natal and breeding sites are not likely to be linear (Wiens 2001). Furthermore, selection of a place to reside by dispersing birds may be conducted in stages (e.g., search, settlement, residency; Stamps 2001), each associated with different behaviors and patterns of movement. Identifying patterns of movement in all stages of dispersal is critical to understanding why dispersing birds settle and breed where they do. Also, information about environments that facilitate movement and survival during dispersal (e.g., Miller et al. 1997) are important in the development of habitat management plans for birds, especially if plans encompass broad spatial scales (e.g., Strong and Bancroft 1994, Miller et al. 1997) and fragmented landscapes (e.g., Temple 1989).

Natal dispersal has been studied in a variety of bird species over the last decade, but information about this process remains limited compared to other aspects of population demography and other kinds of movements (Koenig et al. 2000, Walters 2000, Clobert et al. 2001). Among birds of prey, various stages of natal dispersal have been studied primarily in species that are the focus of management and conservation efforts and in environments that are relatively undeveloped or rural (e.g., Wyllie 1985, Walls and Kenward 1995, Ganey et al. 1998, Harmata et al. 1999, Restani and Mattox 2000). Cooper's Hawks (*Accipiter cooperii*) nest in highly-developed environments (i.e., urban and suburban areas) in several places across North America (see Rosenfield and Bielefeldt 1993 for review, Stewart et al. 1996, Boal and Mannan 1998, 1999), but little is known about the movements, habitat use, or survival of fledglings in these settings. Existing information suggests that Cooper's Hawks may move up to 100 km from their natal

nests in their first fall and winter (Boal 1997), but most reported movements during natal dispersal are considerably less than this distance (e.g., median = 6.4 km for males, N = 10; 14.4 and 79 0 km for two females; Rosenfield and Bielefeldt 1992, Rosenfield et al. 1996). Thus, the initial stages of natal dispersal by Cooper's Hawks hatched in relatively large metropolitan areas could occur within these developed environments.

Knowledge of the patterns of movement and habitat use of dispersing Cooper's Hawks in urban settings could be used to identify environments to protect or enhance as cities grow, assuming that hawk populations are a desired feature of the urban landscape. Furthermore, Boal and Mannan (1999) suggested that models of population growth of urban Cooper's Hawks are needed to understand whether some urban areas represent "source" or "sink" populations (Pulliam 1988). Estimates of survival of hawks during dispersal are critical to such modeling efforts (e.g., Lande 1988, Boyce 1992, Beissinger and Westphal 1998). We followed Cooper's Hawks hatched in an urban setting for up to 6 mo after fledging to: (1) estimate their survival from late summer through early winter; and (2) determine how far they disperse from natal sites, the kinds of environments they use while dispersing, and the characteristics of areas they use when they settle during their first winter.

STUDY AREA

We marked and tracked fledgling Cooper's Hawks in and near Tucson, Arizona (32 N°, 111 W°). The Tucson metropolitan area encompasses about 70 000 ha with an estimated human population of 803 600 residents. Tucson includes developments ranging from commercial districts and high-density housing to suburban areas with low-density housing. Parks, golf courses, and open space are scattered throughout residential areas. Tucson is located in the Sonoran Desert and supports remnants of lower and upper Sonoran vegetation types and riparian corridors (Brown et al. 1979), but much of the natural vegetation has been removed or replaced with nonnative plants.

METHODS

We used bal-chatri traps (Bloom 1987) to capture fledgling Cooper's Hawks at nests monitored in a long-term study (Boal and Mannan 1999, Mannan and Boal 2000). We captured fledglings when they were old enough to hunt on their own and when their rectrices were fully emerged (≥55 d old). We marked each captured fledgling with a Department of Interior leg band and a colored leg band with a unique alpha code, and attached a radiotransmitter (model RI-2C [5 g] in 1999 and model PD-2 [3.5 g] in 2000; Holohil Systems Ltd,

Carp, Ontario, Canada) to a central rectrix (Samuel and Fuller 1994). Estimated life of transmitters was 6 mo (model PD-2) or 9 mo (model RI-2C). No more than two fledglings (usually a male and female) from any nest were radio-tagged, and nests from which fledglings were marked were all >5 km from the edge of the metropolitan area.

We relocated radio-tagged hawks, while they remained in their nest areas, at least once per week by "homing" (White and Garrott 1990) with Telonics TR-2 receivers and RA-14 flexible, two-element, yagi antennas (Telonics-Electronics Consultants, Mesa, AZ). After hawks left their nest areas, we attempted to relocate them by scanning for their radio signals from 40 elevated positions (e.g., hillsides, tops of buildings) once or twice per week. Elevated positions were scattered throughout most of the Tucson metropolitan area so that any radio-tagged hawk present likely would be detected. If a signal was detected from an elevated position, we estimated its general location based on signal strength, and then attempted to locate the hawk by "homing" in an automobile and on foot. In areas without elevated positions, we drove along parallel roads throughout the area and scanned for radio signals. If a hawk settled into a relatively small area where it could be found with consistency (i.e., established a home range), we attempted to relocate it up to five times per week at various times of the day by homing. We allowed at least 12 hr between relocations for any given hawk to minimize the risk of dependency among locations.

Once or twice per month, we flew in a single engine aircraft in parallel transects over the Tucson metropolitan area and scanned for radio signals. We also scanned for radio-tagged hawks while the aircraft was flown along major watercourses up to 100 km from Tucson. If a signal from a radio-tagged hawk was detected from the aircraft, we recorded the general area of the detection, and returned to the area in an automobile to search for the hawk.

Cooper's Hawks in Tucson are acclimated to the presence of humans, and single observers can approach hawks without eliciting flight (Mannan and Boal 2000). Therefore, we attempted to see the hawks at each relocation. Sometimes hawks were out of sight (e.g., in a fenced back yard), but were close enough that their radio signal could be detected with the receiver connected only to the antenna cable (i.e., with the antenna detached). In such cases, we estimated the location of the hawk to be within 30 m of the strongest signal. If a hawk was out-of-sight, in an area where we did not have permission to access, and not within 30 m of the observer, we estimated its position by triangulation. We marked all locations on an atlas of city streets.

Analyses. We plotted all locations of hawks on a digital representation of the streets and land use categories in Tucson (Shaw et al. 1996). We first measured distances between all consecutive locations of each hawk, including locations estimated from aircraft and elevated positions (i.e., in instances where we could not locate hawks by homing). We assigned all locations, except those estimated from aircraft and elevated positions, to one of five categories based on kind of development and level of human use (i.e., low-density residential areas [<7.4 resi-

dences/ha]; high-density residential areas [≥7.4 residences/ha]; open space with low human use [e.g., cemeteries, neighborhood parks, and natural open space], open space with high human use [e.g., golf courses, district and regional parks, and schools], and other [e.g., roadways, and commercial, industrial, and agricultural areas]). If hawks established home ranges during fall and winter, we used the convex polygon method to generate area-observation curves (Odum and Kuenzler 1955) for each home range to assess whether our sample of locations adequately described home range size for the period of interest. We then estimated home range sizes with the kernal method (90% isopleth; Worton 1989). We chose the 90% isopleth because it seemed to minimize fragmentation of home ranges, while excluding areas not used by hawks. We applied a smoothing technique to the boundaries of home ranges based on least squares cross validation (h). We first calculated h for the set of locations for each hawk. We then estimated size of home ranges, and applied the average h to all home ranges (Kenward 2001). We used only locations of hawks identified by sight or triangulation, and those estimated to be within 30 m of the observer, to calculate home ranges. We used program RANGES V (Kenward and Hoddler 1996) to generate area-observation curves, and Arcview Version 3.2 (Environmental Systems Research Institute 1996) with the extension "Animal Movements" (Hooge and Eichenlaub 1997) to measure distances between locations and estimate size of home ranges.

We described habitat use by dispersing hawks before they settled into winter home ranges by calculating the percent of locations (all hawks combined) in each land use category. We could not evaluate habitat selection (i.e., comparing use versus availability) during this period because our sample of locations per hawk was small and we did not have a database identifying land use on the entire area used by dispersing hawks.

We evaluated habitat selection inside winter home ranges by first overlaying outlines of the home ranges on the digital database of land use categories in Tucson (Shaw et al. 1996). We calculated the coverage of each category in each home range, compared the coverages to land use patterns shown on aerial photographs taken in 2001 to assess accuracy, and made corrections in two home ranges. We used compositional analysis (Aebischer et al. 1993) to compare the proportion of coverage of each category to the proportion of hawk locations in each category among all home ranges. We used the Kaplan-Meier (1958) method to estimate survival of radio-tagged hawks. We conducted statistical analyses in the JMP IN 3 Windows Version statistical package (Sall et al 2001) or Resource Selection Analysis Software for Windows (Copyright 1999, Fred Leban).

RESULTS

We radio-tagged 21 hawks in 1999 (10 females and 11 males), and 19 hawks in 2000 (8 females and 11 males). We relocated the 40 hawks a total of 527 times (58.3% by sight, 22.0% with the antenna detached from the receiver in combination with triangulation, 7.4% by triangulation alone,
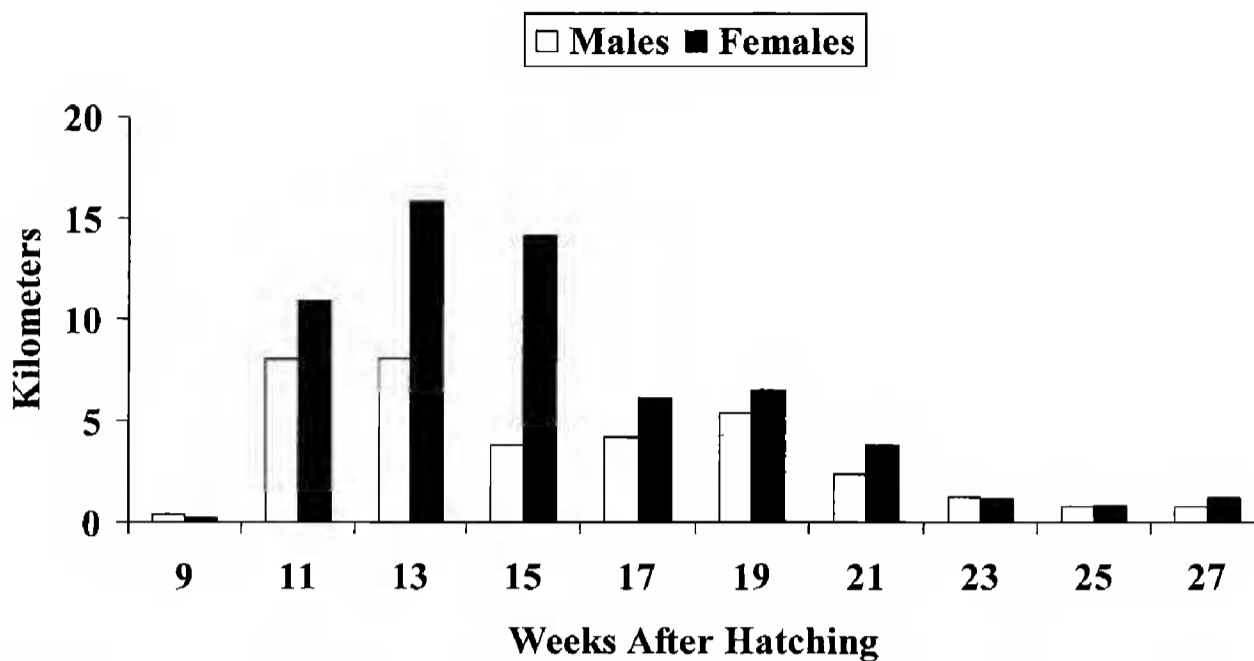
Figure 1. Mean distance between consecutive locations in 2-wk periods for radio-tagged Cooper's Hawks after fledging from nests in Tucson, Arizona, 1999–2000 (N = 4–17 locations for males, and 4–13 for females, depending on period; mean number of days between locations from 11–22 wk after hatching was similar for males [$\bar{x}$ = 6.7, SD = 5.2] and females [$\bar{x}$ = 7.6, SD = 7.4; t-test, P = 0.38]).

7.4% from elevated positions, and 4.9% from aircraft). Six hawks (two females and four males) lost the tail feather on which the radio was attached, and five (three females and two males) died before meaningful information on their movements could be collected. Of the remaining 29 radio-tagged hawks, 19 (eight females and 11 males) either were located sporadically (i.e., $N \leq 9$) throughout the fall, or early in the fall but never again, and 10 (five females and five males) remained within 20 km of the Tucson metropolitan area at least into late October.

Movements. The typical pattern of movements for hawks we were able to track through early winter consisted of sedentary behavior (i.e., short inter-location distances) in the natal area, followed by relatively long movements beginning 11–13 wk after hatching, and finally by sedentary behavior again when hawks established a fall/winter home range (Fig. 1). Inter-location distances were, on average, greater for females ($\bar{x}$ = 6.8 km, range = 0.02–51.7 km, SD = 9.8) than males ($\bar{x}$ = 3.8 km, range = 0.05–20.8 km, SD = 5.4; t-test, P = 0.02; Fig. 1). One female, for example, made two movements of >59 km in a period of <20 d. Siblings did not move together after they left the natal area, and neither males nor females moved in discernable patterns prior to establishing fall/winter home ranges. We generally found hawks of both sexes in scattered locations throughout Tucson before they settled (Fig. 2).

We estimated size of home range during fall/winter for nine of 10 hawks (Table 1). Seven of the nine home ranges had become relatively stable in area by the end of our sampling period ($\leq 5.1\%$ increase in area over at least the last week of sampling), but home ranges of two females were still increasing (8.8 and 13.2%), when the hawk died or the radio failed (Table 1). We did not estimate home range size for one hawk because the sample of locations was small (N = 11) and was obtained during one month (December). Home range size for the nine hawks averaged 771 ha (SD = 403), and did not differ (t-test, P = 0.80) between males ($\bar{x}$ = 804 ha, SD = 456) and females ($\bar{x}$ = 731, SD = 387; Table 1). Distance from center of home range to natal site was nearly twice as far for females ($\bar{x}$ = 10.9 km, range = 4.2–19.5 km, SD = 6.4) as males ($\bar{x}$ = 6.0 km, range = 2.2–13.3 km, SD = 5.0), but the difference was not significant (t-test; P = 0.23). Eight of nine home ranges encompassed one or two traditional nest sites of Cooper's Hawks, but none of the dispersing hawks incorporated their natal nest sites in their fall/winter ranges.

Habitat. We found hawks in a variety of environments after they left their natal areas and before they settled into fall/winter home ranges; environments used included riparian areas (35%; a subcategory of open space), high-density residential areas (25%), low-density residential areas (22.5%), and parks and golf courses (17.5%) (N = 40 lo-
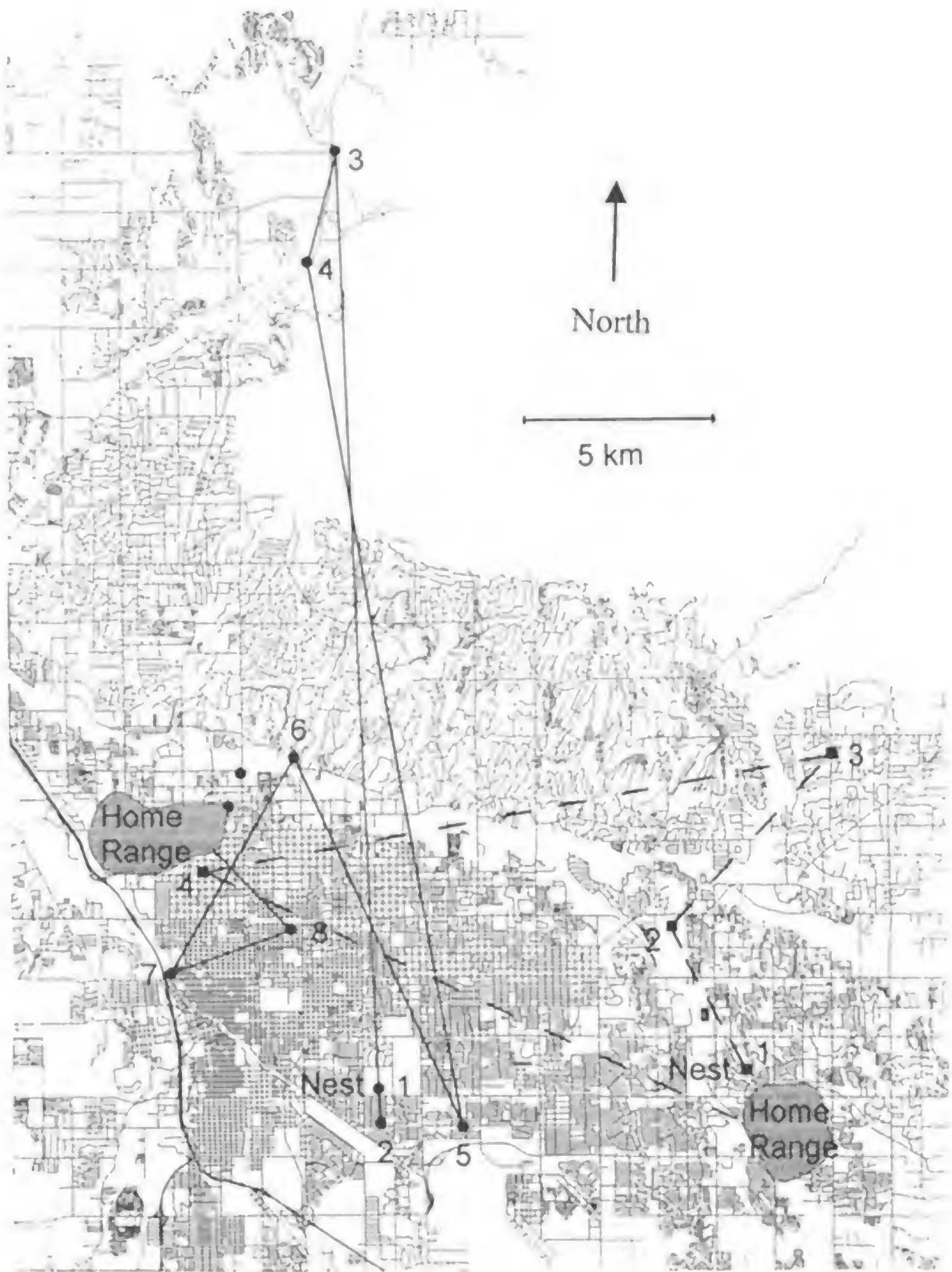
Figure 2.   Sequential movements of two hawks (female = solid line; male = dashed line) between leaving their natal area and settling into a fall/winter home range in Tucson, Arizona, 1999–2000. Multiple locations in the natal area are represented by a single location.

Table 1.   Size of home ranges during fall/winter, and distance from center of these home ranges to natal nests for post-fledgling Cooper's Hawks in Tucson, Arizona, 1999–2000.

HAWK ID[a]	PERIOD TRACKED IN HOME RANGE	N[b]	PERCENT INCREASE[c]	DISTANCE TO NEST[d] (km)	AREA (HA)
M327	16 Sep 99–18 Feb 00	20	4.3	2.2	492
M457	12 Sep 00–2 Dec 00	32	3.6	9.1	537
M885	11 Aug 99–8 Mar 00	73	0.0	2.2	556
M854	16 Aug 99–26 Oct 99	13	5.1	3.1	854
M313	9 Sep 00–11 Dec 00	23	3.2	13.3	1580
F215	26 Aug 00–26 Nov 00	32	8.8	4.2	409
F977	22 July 99–15 Feb 00	63	0.0	10.8	593
F276	23 Sep 00–3 Dec 00	30	13.2	9.2	628
F259	14 Aug 00–13 Nov 00	16	0.0	19.5	1294

[a] M = males; F = females.
[b] Number of relocations identified by sight or triangulation, and those estimated to be within 30 m of the observer.
[c] Increase in area in the home range over at least the last week of sampling, representing at most the last five locations.
[d] Distance from center of the winter home range to natal nest.

cations for all hawks combined, excluding those estimated from aircraft and elevated positions). Once hawks settled, their home ranges also varied in composition. Some encompassed mostly high-density residential areas, others encompassed mostly low-density residential areas, and others were dominated by cemeteries, neighborhood parks and natural open space, or golf courses and district and regional parks (Table 2). We found no discernable pattern of selection among hawks for

land use categories inside home ranges (χ^2 = 6.058, df = 4, P = 0.19; Table 2).

Survival. Survival of radio-tagged hawks through 180 d was 67%. Two males and four females died while we were tracking them, but there was no difference in survival (Wilcoxon test, P = 0.66) between males (75%) and females (64%). Of the six hawks that died, two females were killed by collisions with cars, one male was electrocuted, and three died of unknown causes. Of the 10 hawks we

Table 2.   Percentages of locations within five land use categories[a] in home ranges of fledgling Cooper's Hawks during their first fall/winter in Tucson, Arizona, 1999–2000.

HAWK ID[c]	PERCENT OF LOCATIONS (PERCENT OF HOME RANGE)[b]				
	LOW-DENSITY RESIDENTIAL	HIGH-DENSITY RESIDENTIAL	OPEN SPACE WITH LOW HUMAN USE	OPEN SPACE WITH HIGH HUMAN USE	OTHER
M327	0.0 (6.1)	60.0 (51.4)	15.0 (21.5)	10.0 (11.7)	15.0 (9.3)
M457	78.6 (58.5)	3.6 (12.5)	7.1 (16.7)	0.0 (1.2)	10.7 (11.1)
M885	0.0 (6.7)	78.6 (52.8)	12.9 (17.3)	0.0 (1.9)	8.5 (21.3)
M854	46.1 (37.4)	7.6 (13.4)	38.5 (33.5)	0.0 (4.8)	7.8 (10.9)
M313	16.7 (7.4)	45.8 (34.3)	29.2 (37.6)	0.0 (1.2)	8.3 (19.5)
F215	36.7 (12.9)	13.3 (28.2)	3.3 (6.6)	46.7 (37.7)	0.0 (14.6)
F977	81.4 (72.1)	0.0 (3.3)	10.2 (18.4)	8.4 (5.1)	0.0 (1.1)
F276	0.0 (0.0)	50.0 (54.3)	19.2 (17.8)	26.9 (2.4)	3.9 (25.5)
F259	25.0 (24.7)	31.2 (24.9)	31.2 (39.7)	6.3 (6.4)	6.3 (4.3)

[a] Low-density residential (<7.4 residences/ha); high-density residential (≥7.4 residences/ha); open space with low human use = cemeteries, neighborhood parks and natural open space; open space with high human use = golf courses, district and regional parks, and schools, and other = roadways, and commercial, industrial, and agricultural areas.
[b] χ^2 = 6.058, df = 4, P = 0.19; compositional analysis.
[c] M = males; F = females.

were able to track through early winter, six were known to be alive 2 yr after they were radio-tagged.

DISCUSSION

The wide-ranging movements we detected among fledgling Cooper's Hawks between 11 and 22 wk after hatching are similar to those observed in related species during the early stages of natal dispersal (e.g., Eurasian Sparrowhawks [*Accipiter nisus*] in southern Scotland [Newton 1986:261]), and presumably were explorations in search of a place to settle for the winter. Environmental and social cues that triggered Cooper's Hawks to settle for the fall/winter are unknown, but rich sources of food (e.g., concentrations of birds at bird feeders), and low levels of intraspecific and interspecific competition are likely candidates. A variety of environments were used by hawks during the "exploration" period but riparian systems were used by hawks (35%) more than they generally occur on the landscape (e.g., 6% in the Tucson metropolitan area, Shaw et al. 1996), suggesting that riparian corridors may be attractive to dispersing hawks as sources of food and cover, or facilitate their movements in some manner in the urban environment.

Females disperse farther than males in many species of birds (Greenwood and Harvey 1982). Rosenfield et al. (1996) reported that the median distance moved by 10 male Cooper's Hawks during natal dispersal was 6.4 km, whereas two females moved 14.4 and 79.0 km. We found that females moved greater distances between locations than males, especially from 11–22 weeks after hatching. The wide-ranging movements of females may cause them to settle farther from their natal nests than males, but our small sample of winter home ranges and the restricted area in which we were able to follow hawks precluded definitive assessment of this relationship. The movements of hawks we report herein also may be biased in that some of the hawks we could not locate may have moved farther than those we were able to track; thus, our data may underestimate the distances moved by both sexes. It is also possible that some of the hawks we located only sporadically throughout the fall never established a home range.

Settling and establishing home ranges, even if temporary, after some period of exploration appears to be common during the early stages of natal dispersal of predatory birds (e.g., Beske 1982, Ferrer 1993, Walls and Kenward 1998). Home

ranges of Cooper's Hawks in Tucson during their first fall/winter were, on average, about 11 times larger than the home ranges of breeding males (Mannan and Boal 2000), and typically overlapped one or two traditional breeding ranges. We do not know whether the home ranges established in the first fall/winter of life persist into the following breeding season and beyond, but subsequent observations suggest that the Cooper's Hawks we radio-tagged remained in or close to them for several years. For example, four hawks (three males and one female) nested, attempted to nest, or died 2 or 3 yr after they were radio-tagged at sites that were encompassed by their first winter home ranges. Also, one male and one female hawk, radio-tagged in 2000, nested 2 yr later in sites that were 1.0 and 4.6 km, respectively, from the edges of their first winter home ranges.

Home ranges of the hawks we tracked were dominated by a variety of land use categories, and no consistent pattern of selection by hawks was evident among categories within home ranges. We speculate that Cooper's Hawks during their first fall/winter in Tucson can persist in a variety of urban environments because rich sources of food (e.g., concentrations of birds) are common and widespread (Germaine et al. 1998).

Survival of birds of prey during dispersal is low for many species (e.g., Belthoff and Ritchison 1989, Rohner and Hunter 1996, Ganey et al. 1998, but see Harmata et al. 1999) probably because fledglings are relatively inexperienced in acquiring food and avoiding predators and other agents of mortality. We found survival to be relatively high among Cooper's Hawks in Tucson for 6 mo after fledging. Abundance of food can influence survival of dispersing birds (e.g., Rohner and Hunter 1996), and we propose that an abundance of prey in Tucson may reduce mortality and offset agents of mortality common in developed environments (e.g., collisions with vehicles and windows, electrocution). Our speculation that Tucson provides ample food for Cooper's Hawks is supported by evidence that total density and biomass of birds often is higher in urban than nonurban areas (e.g., in Tucson, Emlen 1974; elsewhere, Beissinger and Osborne 1982, Blair 1996, Marzluff et al. 1998). However, our estimates of survival of fledgling Cooper's Hawks in Tucson may be biased in at least two ways. First, we could have overestimated survival because some of the hawks we could not find may have died. And second, attachment of radio-tags could

have negatively affected the hawks we studied (e.g., R. Reynolds, G. White, S. Joy, and R. Mannan unpubl. data) and led to an underestimate of survival.

Boal (1997) modeled the dynamics of the population of Cooper's Hawks in Tucson, and concluded that it was declining at about 8%/yr, primarily due to a disease (trichomoniasis) that killed about 40% of the nestlings and fledglings each year (Boal et al. 1998, Boal and Mannan 1999). The estimate of survival of juvenile Cooper's Hawks in Tucson reported herein is higher than what Boal (1997) used in his model; thus, notions about whether Tucson is a "source" or "sink" population for Cooper's Hawks could change when revised estimates of post-fledging survival are combined with updated information on adult survival, productivity, and mortality from trichomoniasis and other agents.

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